

Fractional Quantum Hall Effect at $\nu=5/2$: Ground States, Non-Abelian Quasiholes, and Edge Modes in a Microscopic Model

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Introduction

Fractional quantum Hall (FQH) liquids represent novel states of matter with non-trivial topological order. Consequences of such topological order include chiral edge excitations and fractionally charged bulk quasiparticles that obey Abelian or non-Abelian fractional statistics. It has been proposed that the non-Abelian quasiparticles can be used for quantum information storage and processing in an intrinsically fault-tolerant fashion, in which information is stored by the degenerate ground states in the presence of these non-Abelian quasiparticles, and unitary transformations in this Hilbert space can be performed by braiding the quasiparticles. While many Abelian FQH states have been observed and studied in detail, thus far there have been relatively few candidates for the non-Abelian ones. The most promising candidate is the FQH state at Landau level filling fraction $5/2$, discovered two decades ago. The leading candidate for the ground state of this system is the Moore-Read (MR) paired state [1], which has been shown to support fractionally charged, non-Abelian quasiparticles [1]. The MR state received strong support from numerical studies using sphere and torus geometries. However these geometries do not contain any boundary, and are thus not suitable for study of edge states.

Numerical Calculation and Results

In this work [2] we perform detailed numerical studies of edge excitations in the $5/2$ FQH state in finite-size systems with disc geometry, taking into account the inter-electron Coulomb interaction and a semi-realistic model of the confining potential due to neutralizing background charge. We use a microscopic model of a two-dimensional electron gas (2DEG) confined to a two-dimensional disk, with neutralizing background charge distributed uniformly on a parallel disk of radius a at a distance d above the 2DEG. This distance parameterizes the strength of the confining potential, which decreases with increasing d . For filling fraction $5/2$, we explicitly keep the electronic states in the first excited Landau level only, while neglecting the spin up and down electrons in the lowest Landau level, assuming they are inert. The amount of positive background charge is chosen to be equal to that of the half-filled first excited Landau level, so the system is neutral.

For a limited and very small range of d , we find the ground state does indeed have the same quantum number of, and has substantial overlap (up to 50%), with the MR state. Within this parameter space we are able to identify the existence of chiral fermionic and bosonic edge modes, in agreement with previous prediction. We have also obtained the velocities of both modes, and found that fermionic mode velocity is much lower than that of the bosonic mode. With suitable short-range repulsive potential at the center, we show that a charge $+e/4$ quasihole can be localized at the center of the system, and its presence changes the spectrum of the fermionic edge mode. This confirms the existence and non-Abelian nature of such fractionally charged quasiparticles. Other competing, like stripes and the anti-Pfaffian, have also been identified.

Conclusions

- The MR Pfaffian and anti-Pfaffian states can be stabilized by adjusting confining potential.
- A small change in confining potential (say by gating) may lead to qualitative change in edge properties.
- Using the mode velocities obtained, we estimate the coherence length is about 4 micron at $T=10\text{mK}$.

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References

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